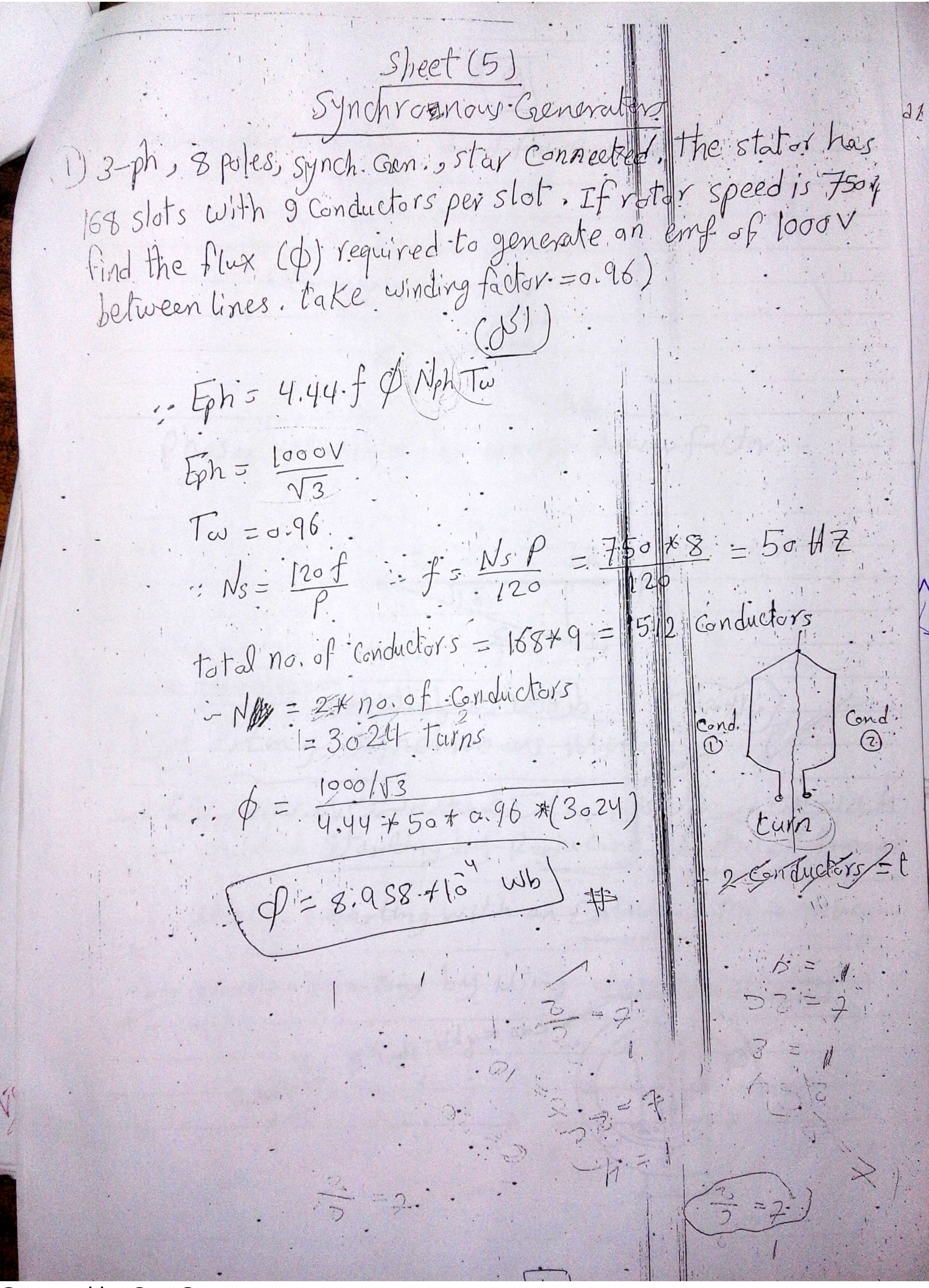


Sheet (5)

Synchronous Generators

1) 3-ph, 8 poles, synch. Gen., star connected, the stator has 168 slots with 9 conductors per slot. If rotor speed is 750 r/m find the flux (ϕ) required to generate an emf of 1000 V between lines. take winding factor = 0.96)

(Sol)

$\because E_{ph} = 4.44 \cdot f \, \phi \, N_{ph} \, T_w$

$E_{ph} = \frac{1000V}{\sqrt{3}}$

$T_w = 0.96$

$\because N_s = \frac{120 f}{P} \quad \therefore f = \frac{N_s P}{120} = \frac{750 * 8}{120} = 50 \text{ HZ}$

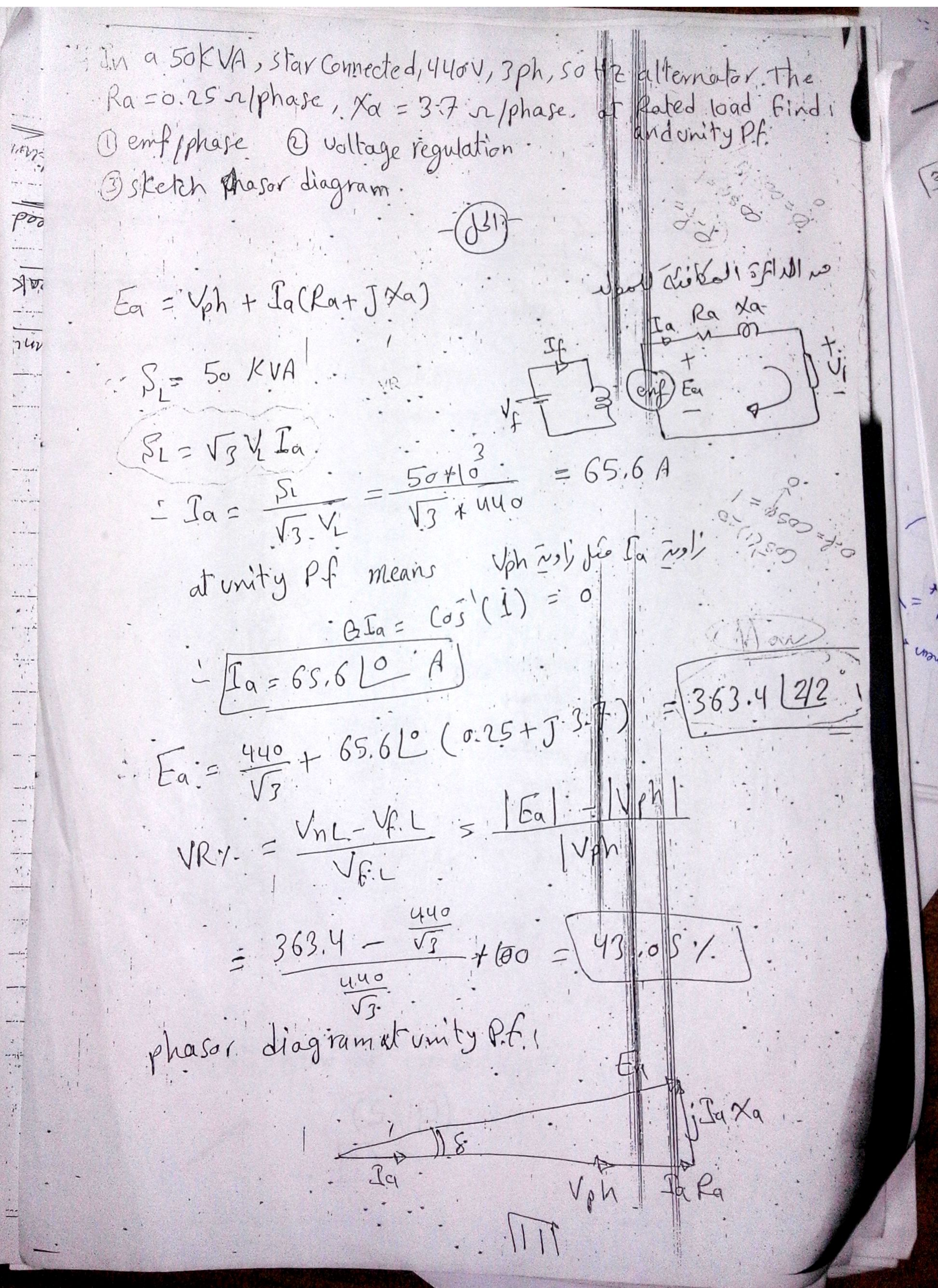
total no. of conductors $= 168 * 9 = 1512$ conductors

$\therefore N_{ph} = \frac{\cancel{2 *} \text{ no. of Conductors}}{2}$

$= 3024$ Turns

$\therefore \phi = \frac{1000/\sqrt{3}}{4.44 * 50 * 0.96 * (3024)}$

$\boxed{\phi = 8.958 * 10^{-4} \text{ Wb}}$



In a 50KVA, star connected, 440V, 3ph, 50 Hz alternator. The $R_a = 0.25\ \Omega/\text{phase}$, $X_a = 3.7\ \Omega/\text{phase}$. at Rated load and unity P.f. find:

① emf/phase ② voltage regulation

③ sketch phasor diagram.

(الحل)

$$E_a = V_{ph} + I_a(R_a + jX_a)$$

$\because S_L = 50\ KVA$

$$S_L = \sqrt{3}\, V_L I_a$$

$$\therefore I_a = \frac{S_L}{\sqrt{3}\, V_L} = \frac{50 \times 10^3}{\sqrt{3} \times 440} = 65.6\ A$$

at unity Pf means زاوية I_a مثل زاوية V_{ph}

$$\theta I_a = \cos^{-1}(1) = 0$$

$$\therefore \boxed{I_a = 65.6\angle 0\ A}$$

$$\therefore E_a = \frac{440}{\sqrt{3}} + 65.6\angle 0\,(0.25 + j3.7) = \boxed{363.4\angle 42}$$

$$VR\% = \frac{V_{nL} - V_{f.L}}{V_{f.L}} = \frac{|E_a| - |V_{ph}|}{|V_{ph}|}$$

$$= \frac{363.4 - \frac{440}{\sqrt{3}}}{\frac{440}{\sqrt{3}}} \times 100 = \boxed{43.05\ \%}$$

phasor diagram at unity P.f.:

Sheet (5) ابن حلول

[3] $P_{out} = 5kw$, $V_L = 110V$, $I_a = 29A$ lag P-f , $f = 50 HZ$
$N_s = 1000 rpm$, $R_a = 0.1 \Omega/ph$, $X_s = 1.53 \Omega/ph$
$I_f \Rightarrow I_{f1}$ at full load
field Current

[a] Req: ① E_{aph} ② VR% ③ no. of poles (p)

-الحل-

$\because N_s = \frac{120f}{p}$ $\therefore p = \frac{120f}{N_s} = \frac{120*5}{1000} =$ 6 poles

$\Rightarrow E_{aph} = V_{ph}\angle 0° + I_a(R_a + jX_s)$

R_a jX_s I_a + V_{ph} − E_{aph} R_f I_f V_f

$\because P_{out} = 5*10^3 = \sqrt{3}\, V_L\, I_a \cos\phi$

$\therefore \cos\phi = \frac{5*10^3}{\sqrt{3} * 110 * 29} = 0.905$

$\Rightarrow I_a = 29 \angle -\cos^{-1}(0.905) = 29 \angle -25.1°$

$\therefore E_{aph} = \frac{110}{\sqrt{3}} + (29\angle -25.1° * (0.1 + j1.53)) =$ $93.5 \angle 24.63°$ V

$\therefore VR\% = \frac{E_{aph} - V_{ph}}{V_{ph}} * 100 = \frac{93.5 - \frac{110}{\sqrt{3}}}{\frac{110}{\sqrt{3}}} =$ 47.22%

[b] if field current is reduced to 0.9 I_{f1} while speed is Constant find the load Voltage if supply the same load at the same P-f ? ($V_{ph} = ?!$)

$\because I_{f2} = 0.9 I_{f1}$ $\therefore E_{ph2} = 0.9 E_{ph}$

$\therefore I_{a2} = 29 \angle -25.1°$ A والتيار كما هو

$\because E_{ph} = V_{ph} + I_a(R_a + jX_s)$

$\therefore V_{ph_2} = E_{ph_2} - I_a(R_a + jX_s)$

معتمدة على إثبات ملف ← $\because I_a \cos\varphi = \text{constant}$

$\because E_{ph} \sin\delta = \text{constant}$

هو قابل (ظل ثابت) التيار والـ p.f

$\therefore E_{ph} \sin\delta = E_{ph_2} \sin\delta_2$

$E_{ph} \sin\delta = 0.9\, E_{ph} \sin\delta_2$

$\therefore \sin(24.63) = 0.9 * \sin\delta_2$

$\therefore \delta_2 = 27.5^\circ$

$\therefore V_{ph_2} = 0.9 * 93.5 \angle 27.5 - (29\angle -25.1 * (0.1 + j1.53))$

$\therefore V_{ph_2} =$

[c] If the speed, field current & load current are kept constant, the P.f changed to 0.8 lead, $V_{ph_3} = ?$

مقدار $E_{ph_3} = E_{ph}$, $I_{f_3} = I_f$, $N = \text{Const}$

$\therefore I_{a3} = 29 \angle +\cos^{-1}(0.8) = 29 \angle 36.87^\circ$

$\therefore V_{ph3} = E_{ph3} - I_{a3}(R_a + jX_s)$

$V_{ph3} = 93.5 \angle \delta_3 - (29\angle 36.87) * (0.1 + j1.53)$

لابد من حساب δ_3 أولاً

$\therefore V_{ph3} + J*(0) = 93.5 \cos\delta_3 + j\, 93.5 \sin\delta_3 + 24.3 + j\, 37.36$

بمساواة الـ Real مع الـ Real والتخيلي مع التخيلي

$\therefore J*(0) = 0 = 93.5 \sin\delta_3 + 37.36$

$\therefore \boxed{\delta_3 = 23.4^\circ}$

$\therefore V_{ph3} = 93.5\angle 23.4 + (29\angle 36.87\,(0.1 + j1.53)) = ✓$

1) P = 6 poles, 3ph, star, $P_{out} = 100$ KW, P.f. = 0.8 lead
$f = 60$ Hz, $V_L = 2$ KV, $R_a = 0.4\ \Omega/ph$, $X_s = 4\ \Omega/ph$
find ① VR% ② max. developed Power ③ $\eta\%$ if $P_r = 10$ Kw → Prot. مفاقيد دورانية

الأول

$$\because V_{ph} = \frac{2 * 10^3}{\sqrt{3}} \angle 0$$

$$E_{ph} = V_{ph} + I_a (R_a + jX_s)$$

$$\because P_{out} = \sqrt{3}\, V_L I_a \cos\phi$$

$$\therefore I_a = \frac{100 * 10^3}{\sqrt{3} * 2 * 10^3 * 0.8} = 36.1$$

$$\therefore I_a = 36.1 \angle 36.87^\circ \text{ A}$$

$$\therefore E_{ph} = \frac{2 * 10^3}{\sqrt{3}} \angle 0 + (36.1 \angle 36.87) * (0.4 + j4)$$

$$\therefore E_{ph} = 1086.7 \angle 6.6 \text{ V}$$

$$VR\% = \frac{E_{ph} - V_{ph}}{V_{ph}} * 100 = \frac{1086.7 - \frac{2000}{\sqrt{3}}}{\frac{2000}{\sqrt{3}}}$$

$$\therefore VR\% = -5.88\%$$

سالب لأن الحمل Lead
ويطلع موجب لو الحمل Lag

[illegible] أيضاً

$$P_{max} = \frac{V_{ph} * E_{ph}}{X_s}$$

$$\therefore P_{max} = \frac{\frac{2000}{\sqrt{3}} * 1086.7}{4} = 341 \text{ KW}$$

$$\eta\% = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{losses}} = 89\%$$

P_{losses} → P_{copper}, P_{fri}

$P_{copper} = 3 I_a^2 R_a = 3(36.1)^2 * 0.1$

P_{fri} or Prot. → معطى $10 * 10^3$ W

⑤

) $S = 40\,KVA$, 380 V, 4 pole, 50 Hz, star connected syn
$R_a = 0.04\,\Omega/ph$, $X_s = 0.42\,\Omega/ph$, $T_{ph} = 100$ turns/ph
Find: (1) E_{ph} at full load with 0.8 lag P.f, VR%.
(2) N_s
(3) ϕ

-الحل-

$$V_{ph} = \frac{380}{\sqrt{3}} = 220\angle 0^\circ\ V$$

$$I_a = \frac{S}{\sqrt{3}\,V_L} = \frac{40*10^3}{\sqrt{3}*380} = 60.77\angle -36.87^\circ\ A$$

$$\therefore E_{ph} = V_{ph} + I_a(R_a + jX_s) = \frac{220}{\sqrt{3}}\angle 0 + (60.77\angle -36.87)(0.04 + j0.42)$$

$$\therefore \boxed{E_{ph} = 237.2\angle 4.35^\circ\ V}$$

$$VR\% = \frac{E_{ph} - V_{ph}}{V_{ph}} * 100 = \frac{237.2 - 220}{220} = \boxed{37.82\%}$$

$$N_s = \frac{120 f}{P} = \frac{120 * 50}{4} = \boxed{1500\ rpm}$$

$\phi \rightarrow$ $\therefore \boxed{E_{ph} = 4.44\,\phi\, f\, T_{ph}\,(K_w)}$ → لو لم يعطى نفرض = 1

$$\therefore \phi = \frac{E_{ph}}{4.44\, f\, T_{ph}} = \frac{237.2}{4.44 * 50 * 100}$$

$$\boxed{\therefore \phi = 0.0107\ W}$$ → weber ويبر